DISCOVER NEW ZEALAND

VOLCANIC PLACES

THE SHAKY ISLES

Signs of volcanic activity are frequent in New Zealand. Often spectacular, the thermal vents and hot spots are a reminder that the earth is still changing. These pictures from the thermal regions show how the energy of the earth breaks through the surface in spectacular and often dangerous displays. These surface signs are traced to the activity underground. Many New Zealanders are unaware how close to disaster they live. Here is the beauty and fascination of living with volcanic risk.

FRONT COVER
Emerald lakes on Mt Tongariro fill old explosion craters.

BACK COVER
Muddy Devil's Cauldron at Tikitere (or Hell's Gate) near Rotorua, with steaming lake beyond.

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Volcanic Places

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and text by
GORDON ELL

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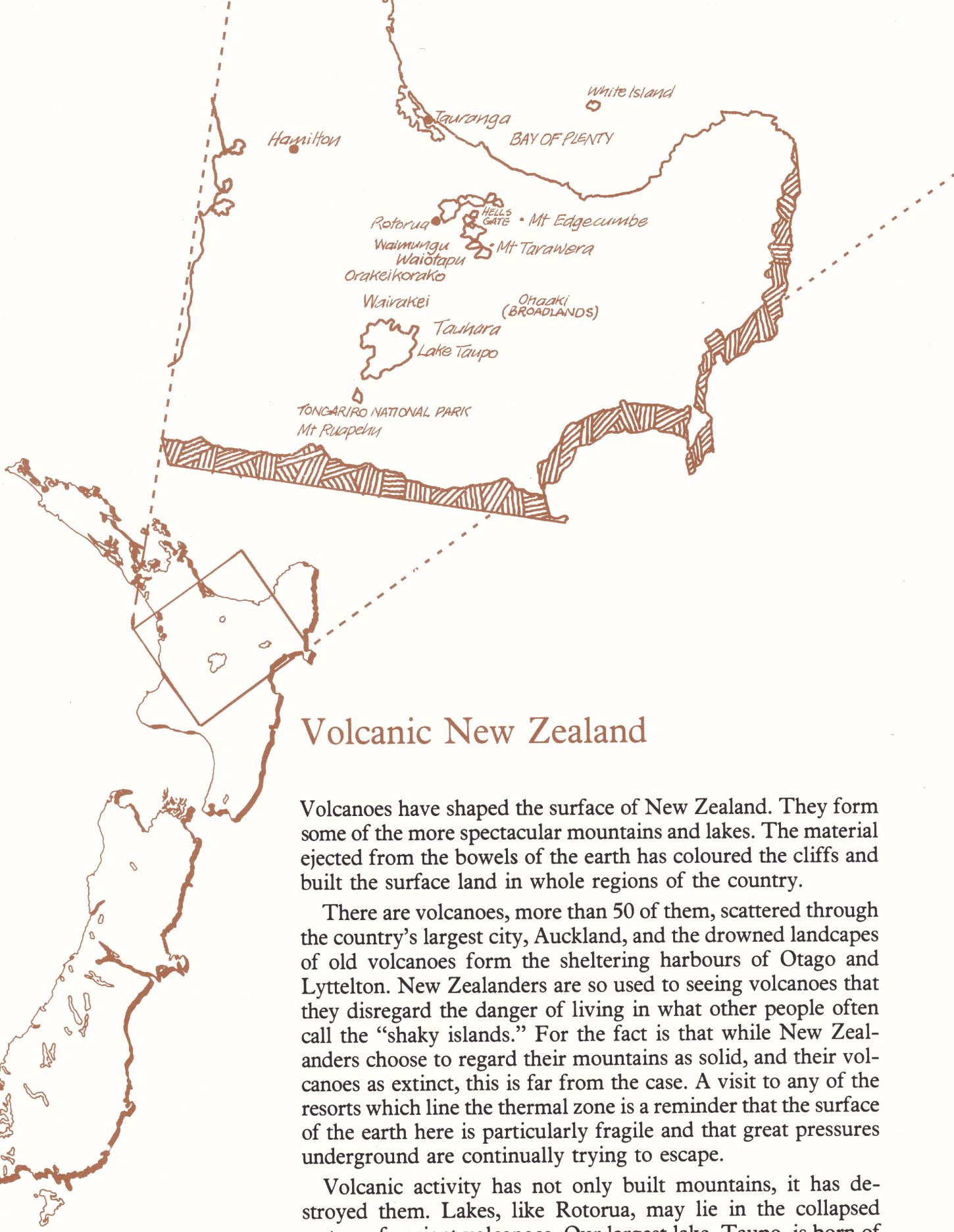
HERITAGE of
NEW ZEALAND



Volcanic New Zealand

Volcanoes have shaped the surface of New Zealand. They form some of the more spectacular mountains and lakes. The material ejected from the bowels of the earth has coloured the cliffs and built the surface land in whole regions of the country.

There are volcanoes, more than 50 of them, scattered through the country's largest city, Auckland, and the drowned landcapes of old volcanoes form the sheltering harbours of Otago and Lyttelton. New Zealanders are so used to seeing volcanoes that they disregard the danger of living in what other people often call the "shaky islands." For the fact is that while New Zealanders choose to regard their mountains as solid, and their volcanoes as extinct, this is far from the case. A visit to any of the resorts which line the thermal zone is a reminder that the surface of the earth here is particularly fragile and that great pressures underground are continually trying to escape.

Volcanic activity has not only built mountains, it has destroyed them. Lakes, like Rotorua, may lie in the collapsed craters of ancient volcanoes. Our largest lake, Taupo, is born of vast explosions: a huge eruption 20,000 years ago may have

accounted for much of its present shape. Again, less than 2000 years ago, Taupo scattered ash for thousands of square kilometres, to cover much of the land towards Rotorua and Waikato.

There is the brooding evidence of Tarawera, and the village it buried in 1886, as a reminder that what appears as solid ground can wreak havoc in just one night of disaster. A skiing holiday at Ruapehu may be interrupted with warning sirens when the crater lake begins to bubble. Every few years Ruapehu and its companion mountains erupt with frightening force.

There are smaller signs too. All through the Rotorua and Taupo districts steam and boiling mud break through the earth. Tourists come from all around the world to see geysers, boiling mud pools, hot lakes and fumaroles; yet local people have learned to live with these phenomena. On the Rotorua golf course boiling mudpools serve as natural hazards. Local people use the geothermal steam to warm their homes. For centuries the Maori people have used their hotpools as a place to steam cook food.

While the Volcanic Plateau and the region of the Hot Lakes are more famous for their volcanic activity, little pockets of underground heat create active thermal features in many corners of the country. Not all are volcanic for hot springs can begin wherever surface water trickles into the warmer depths of the earth. In the far north a complex of mudpools near Kaikohe is used as a health spa. Soda springs surface at points along the highways. About Auckland there are hotpool resorts at Miranda, Helensville and Waiwera. There are more too along the line of the Kaimai Ranges. In the South Island fissures in the earth, about the main ranges, creates hot springs on the Lewis Pass, at Hanmer and by the frozen icefields of the Franz Joseph Glacier.

The reason that New Zealand is so rich in volcanic activity is because of its place, along a weakness in the earth's crust, a fault in the surface skin that some people call the Pacific Ring of Fire.

The Ring of Fire

An earth scientist's globe will show the surface of the world divided into vast and moving plates. The lines that divide these surface crusts of earth are weak points where molten magma can easily burst through. New Zealand is a chain of islands thrust up from the ocean bed along such a line. The fault surrounds the Pacific Ocean where the continental blocks press against the plate which holds the sea. Because of its volcanic nature, this boundary is sometimes called the Pacific Ring of Fire.

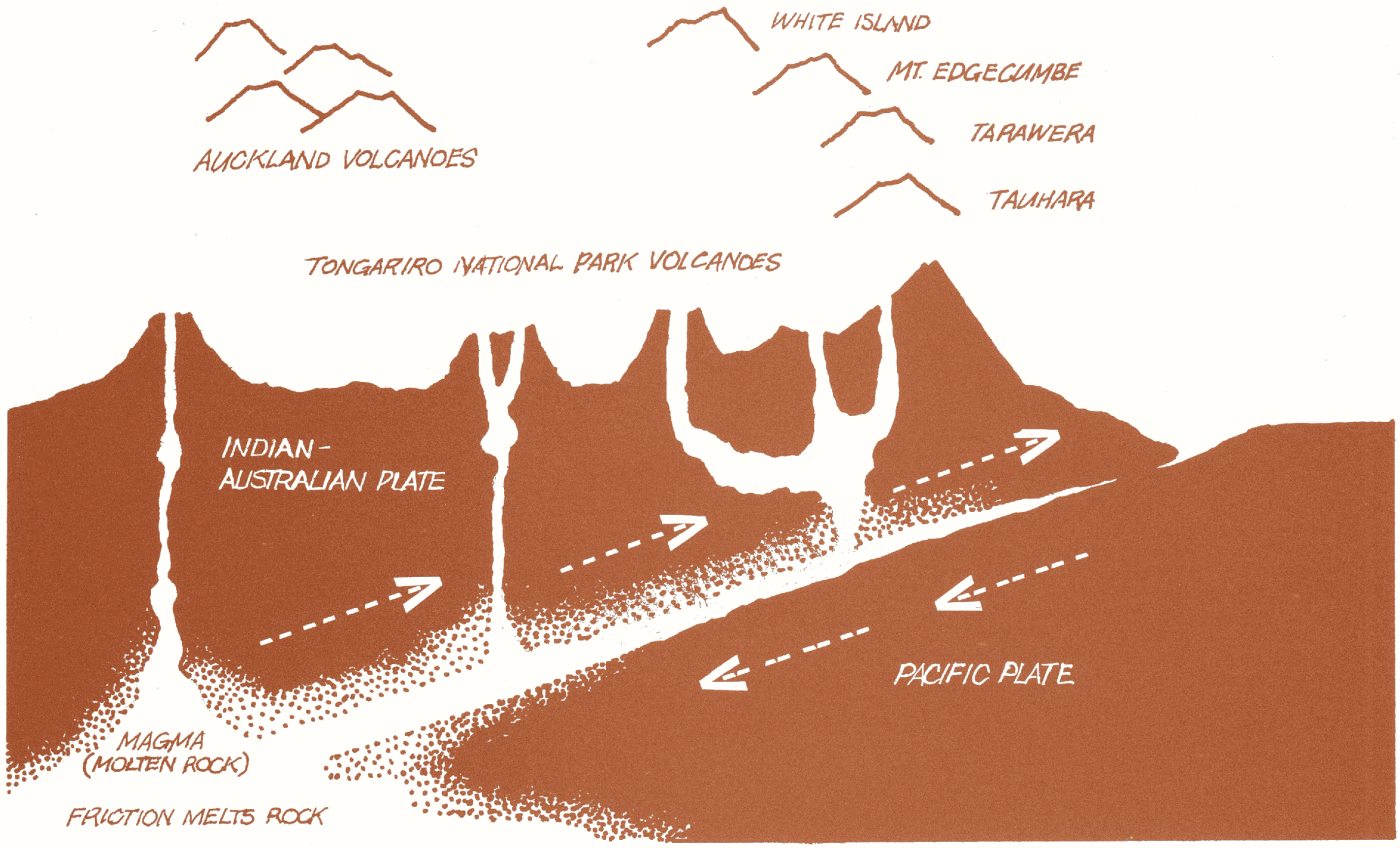
Such places, where the plates of the earth buffet against each other, are continually moving. That brings earthquakes and great temperatures as rock mass grinds against rock mass. The

escaping heat brings molten rock and super-heated steam to the surface as volcanic activity.

The crust of the earth is quite thin; perhaps 8 kilometres beneath the oceans and 30 to 60 kilometres beneath the continents. If it were possible to drill down straight, the temperature may rise some 30°C in every kilometre. Where two crusts of the earth are thrusting against each other the temperature rises even more rapidly. There the friction melts the rock which may run to the surface, through a weak spot, to form a volcano. Water trickling underground may also meet the hotter rocks and become "superheated" under pressure or simply turn to steam. Then it too rises to the surface, perhaps to form a geyser, or hotlake. Sometimes it liquifies the surface earth and turns the ground into boiling mud.

The fascinating variety of volcanic activity happens because each part of the earth is different. Sometimes huge pressures of underground gas build up and volcanoes explosively erupt. In other places they simply ease themselves in a gentle lava flow. The season and the amount of surface water will affect the force and direction of steam vents and mudpools. The blocking of a vent may stop activity. It may, however, lead to a new eruption nearby or a further explosion to relieve the pressure. The kind of rock under the earth may determine the type of activity.

HOW A VOLCANO WORKS

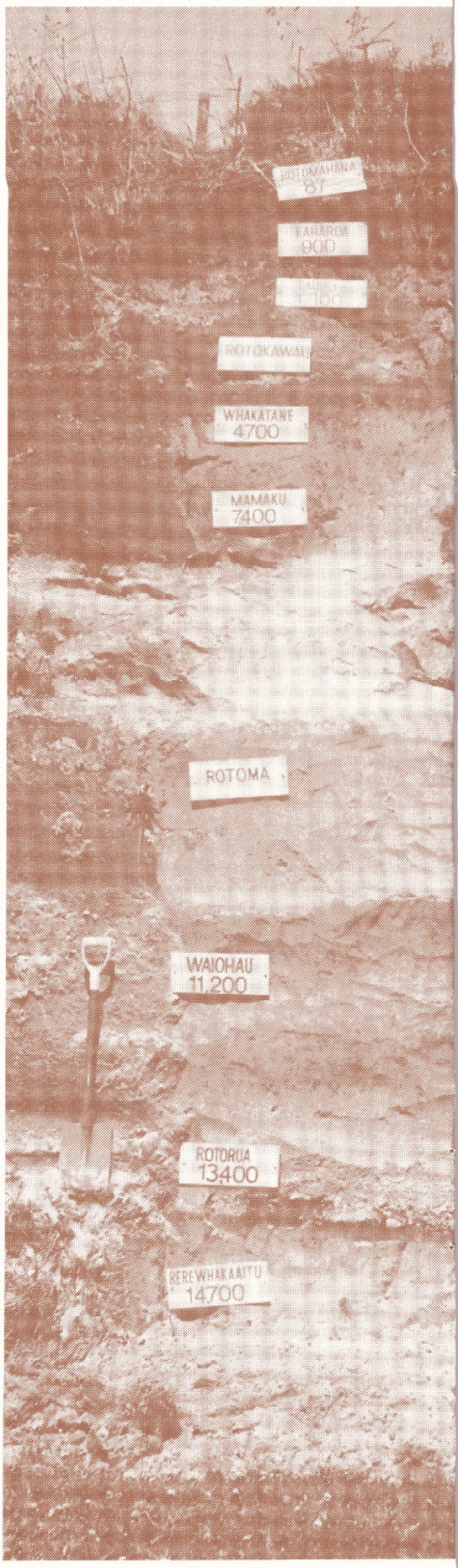


Tongariro — an active volcano

Volcanic steam issues from the crater of Mt Ngauruhoe, 2291 metres, in the Tongariro National Park. This winter scene shows the profile of the Tongariro volcano of which Mt Ngauruhoe is the most active vent. Born perhaps 2500 years ago Ngauruhoe occasionally erupts "ash" and lava. The bulk of Tongariro, on left, rises to 1959 metres and includes several craters and crater lakes. Activity includes the Ketetahi Springs on the northern flank.

KETETAHI SPRINGS on Mt Tongariro is an active volcanic valley of hot springs and fumaroles stretching for almost a kilometre. Wreathed in steam and escaping gas it is an hazardous place. Trampers follow a marked track but need to use commonsense as activity constantly alters the landscape.

Volcanic Eruptions



By bringing molten rocks to the surface, volcanoes can deposit useful minerals on the surface of the earth. The molten rock (magma) may cool in various forms such as andesite or basalt. Inside these rocks there may be crystals or precious metals. Their composition is determined by the kinds of rock beneath the earth, and the affects on them of heat.

Magma, flowing from the mouth of a volcano, is known as lava. Sometimes it flows quite swiftly forming a surface skin while molten rock, at 1000°C. or more, rushes underneath like an underground river. At other times it moves slowly, twisting and breaking as it cools, into piles of broken rock and scoria. There may be "bombs" of rock thrown from the volcano as molten lumps, reshaped as they cool, falling to earth like giant stone teardrops.

The flowing rivers of basalt are sometimes called pahoehoe and produce billowing forms, pillows of lava as may be seen in the cliffs at Oamaru and at Muriwai, west of Auckland. The broken surface of the aa type eruption can be seen on Rangitoto and the scoria fields about the Auckland volcanoes, and Mt Tongariro.

Gases, erupting with the molten rock, may roar up into the sky in vast clouds, like smoke. In some cases they carry lighter-material with them, "ash" and pumice, which may then coat the land. Pumice is a rock light enough to float on water: gas has filled it with holes which help it float and pumice from the central North Island is often found on west coast beaches, washed down to the sea by the Waikato river.

Tephra is a name used by geologists to describe material ejected as particles by a volcano (lava by contrast flows as a mass). Volcanic "ash" is a form of tephra, not cinders, for there is little burning in the volcano. The "smoke" and "fire" are actually gases escaping from the molten rock. A large content of that gas is steam and most "smoke" is ash-charged steam.

Volcanic eruptions may vary in violence with the amount of gas built up in the molten rock. Where the rock is free-flowing the volcano may erupt quite gently, the basalt lava streaming away from the crater, as the gases escape easily into the atmosphere. This is how the little volcanoes of the Auckland isthmus were born.

Where the rock is thick and tacky, in its molten form, then the gases find difficulty in escaping. The result may be a catastrophic explosion. In such a way great clouds of gas lifted the heart out of Lake Taupo in a huge eruption recorded as a darkening of the skies, by the ancient Greeks and Romans, on the other side of the earth. Molten rock is carried high into the air, often

expanding with the gases, to form great showers of pumice which falls then on the land.

In another kind of eruption gas may escape across the surface of the land carrying with it a wall of hot sand, molten glass fragments and pumice. The rush of material flattens the forest and settles as a mantle across the land. In such a way the central North Island has been built up into the Volcanic Plateau. Successive pumice showers overlay thick beds of ignimbrite rocks created by these gaseous eruptions.

Much of the central North Island, north from Taupo and Tarawera, is covered in tephra from volcanic explosions. It may be seen, in layers from successive eruptions, in places like road-cuttings and riverbanks. The roots and branches of trees, overcome by the eruptions, are often still to be seen in the layers. Geologists have put names to the various "ash showers", the layers of mud and pumice which cover the land. Like a layer cake they show the extent and violence of various eruptions. The Tarawera eruption of 1886 scattered pumice over some 900 square kilometres while the Taupo eruption some 1800 years ago covered some 6000 square kilometres, with drifting material also reported from hundreds of kilometres away in the Pacific.

The weather and existing rivers may re-sort the deposits of "ash". A river, held back by a new fall of ash, may form a temporary pond. When the dam of soft material bursts then the rush of water may coat the countryside in volcanic mud. Such mud flows may leave hillocks on the land, called lahars, as can be seen approaching the Chateau Tongariro and about Mt Taranaki. A mud-flow, bursting from the crater lake of Ruapehu in 1953, swept down the Tangiwai river washing out a railway bridge, causing the deaths of 151 people when an overnight express train plunged into the river.

The kinds of minerals produced by the volcanoes depend on the kinds of rocks melted underground. Broken fields of basalt may produce the red scoria used in roading work. Sometimes rocks fuse to form glass particles and even sheets of black glass called obsidian. Maori people used splinters of this glass from Mayor Island and Northland as tools to cut and scrape food.

A succession of volcanic eruptions recorded in their ash deposits and revealed in a road cutting near Rotorua. Dates suggest years since each eruption. Photograph courtesy B. F. Houghton, D.S.I.R.

Volcanoes of Tongariro National Park

The complex of volcanoes in the central North Island is protected within the Tongariro National Park. (See also earlier colour plates and front cover).

Above, the Crater Lake of Mt Ruapehu, splashes the surrounding snow with volcanic mud. Eruptions may take the form of a flow of mud down the mountainside or more spectacular activity. Ruapehu (bottom right) has a series of older craters across its three-kilometre summit. The Tama Lakes (on right) are another form of volcano — the lakes fill explosion craters on the saddle between Mt Ngauruhoe and Mt Ruapehu.

At left are some of the extensive summit craters of Mt Tongariro. The aquamarine lakes are coloured by their chemical origin. Tongariro is still active, through its Ngauruhoe vent, and places like Ketetahi Springs and Red Crater (bottom left) where escaping steam and gas may be seen.

Tongariro National Park—The active volcanoes

The volcanoes of the Tongariro National Park are still active. Exploring them on foot makes a fine adventure. The region can be dangerous however, for not only is there a varying degree of risk, depending on the activity, but the position of the volcanoes is exposed and snowstorms can sweep down at any time. Even in midsummer the sunshine can turn to snow in a few minutes and the walker needs to be prepared.

Fortunately the National Park Board runs an excellent series of guided walks and talks in holiday seasons, a programme which makes it possible for any active person to visit the very tops of the volcanoes and see their activity. The pictures on the accompanying pages were taken while exploring the mountains on such expeditions.

Viewed from afar the volcanoes of the central North Island appear as three major peaks: Tongariro, Ngauruhoe and Ruapehu. Yet these are not all for there are neighbouring cones like Pihanga and Hauhungatahi, and the lake craters about the mountains which are all part of the active zone. Ngauruhoe is regarded as an extension of Tongariro, while on Tongariro itself there are several craters and a very active thermal field. While part of the same zone, Ruapehu is distinct from Tongariro for they have separate magma chambers below.

Ngauruhoe is usually the most active of the Tongariro volcanoes having been created perhaps only 2500 years ago. Its steep, 30 degree slopes, form a spectacular cone of lava and ash layers. The rocky, broken surface makes it an uncomfortable scramble to the crater rim about 2291 metres. There is usually a discharge of steam and occasionally spectacular bouts of activity producing ash and lava flows. A cone within the crater was built during the eruption of 1954 which spewed boulders and lava 300 metres into the air.

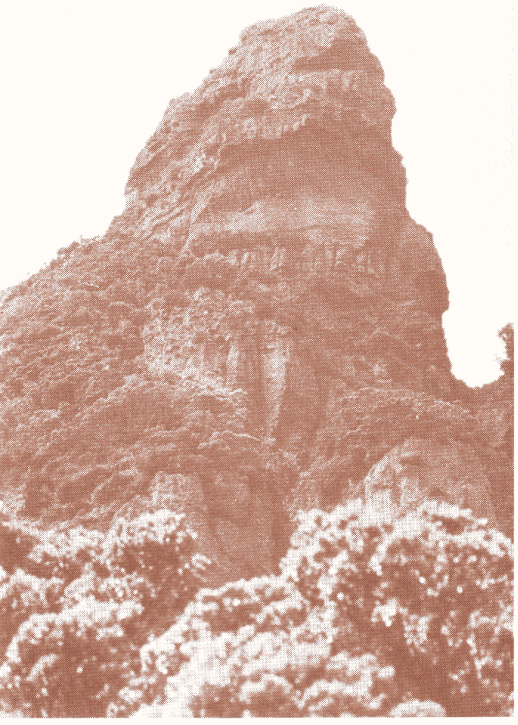
The cratered top of Tongariro includes several points of activity, including fumaroles about the Red Crater, and an extensive area of hot springs and vents at Ketetahi on the northern flank of the mountain. When walking up to Ketetahi the sight of a broad valley full of broken lava is a reminder of activity here from the Te Mari craters. The springs themselves extend up a valley for about a kilometre, clouded in steam and roaring with underground pressures. On the mountain top itself vast flat craters and lakes show the sites of earlier eruptions. In one crater hummocks of lava are piled where they have more recently leaked. Steam escapes from the broken cliffs of the Red Crater and from the adjacent shores of the Emerald Lake.

On the flank of Mt Ngauruhoe two deep explosion craters are now filled with blue water. Called the Tama Lakes they lie on an exposed saddle leading towards the great bulk of Ruapehu.

At 2797 metres Ruapehu presents the highest peak in the central North Island. Along its 3km summit are signs of several craters. The still-active Crater Lake varies in temperature with the degree of volcanic heat below. Often it boils and erupts hot mud which stains the surrounding snow and icefields. A particularly active eruption may send a stream of mud and snow down the mountain side. The crater is continually monitored by scientific instruments to warn of eruptions and reduce the risk to people skiing on the mountain or indeed living in the vicinity of the park.

A major eruption occurred on both Ruapehu and Ngauruhoe in 1975 and spectacular eruptions, sending gas, steam and ash hundreds of metres into the air, may occur every few years.

Volcanic Shapes



The cones of mountains like Ngauruhoe and Taranaki are easy to identify as volcanoes. Yet there are other landforms wrought by volcanic activity which are not so obviously formed in this way. In places cataclysmic explosions have blown a hole in the earth which is now filled with a lake like Taupo, or the sea. Perhaps a giant volcano has emptied itself and the countryside above has collapsed, into the giant chamber which once held molten rock, as around Lake Rotorua. Sometimes molten rock has simply oozed up from a fissure and built up a dome of rock like Mt Ngongotaha at Rotorua.

Erosion can in time reveal other forms, such as the plugs and dykes which were once the molten skeletons of long-lost volcanoes, like the Coromandel Ranges.

Cone volcanoes are quite easy to find in northern New Zealand. Often they are quite small, less than 100 metres high, rising perhaps on the edge of a volcanic field, like Te Heuheu's Redoubt at Tokaanu by Lake Taupo, or the little Bay of Islands and Auckland cones. Their form is quickly produced, perhaps within two or three years, as basalt-type volcanoes rapidly exhaust their magma. Other cones, like Ngauruhoe, are built up over centuries from steep layers of lava and ash.

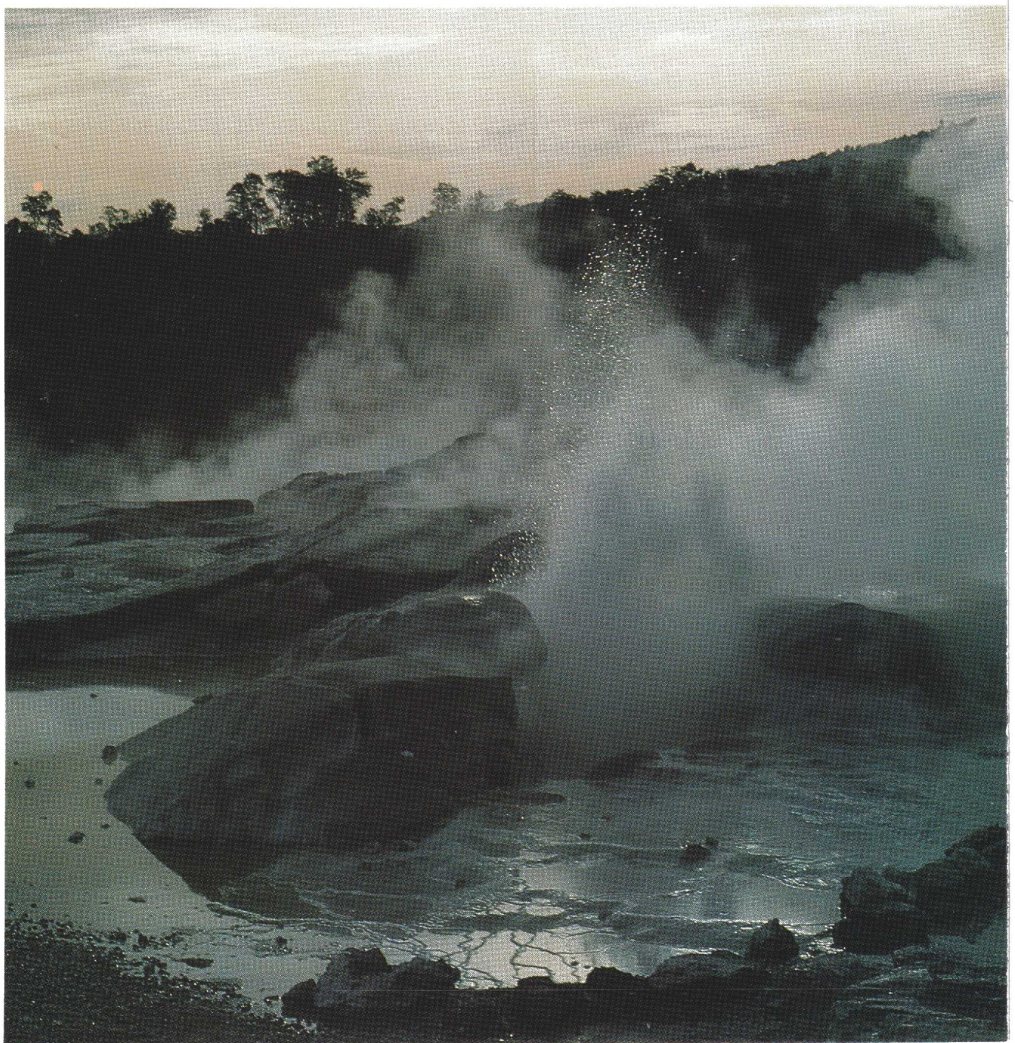
Such cones may produce secondary outlets as their main throat becomes blocked with cooling magma. Rangitoto in Auckland harbour has small scoria cones, near its summit, surrounding the main crater. Ngauruhoe has one inside its crater.

Often the craters of volcanoes contain small lakes, or swamps. In the Rotorua district there are many steep-sided, circular lakes and punchbowl craters, in the forested hills.

Geysers

Pressure of underground steam escaping from a narrow vent can form a geyser. At Whakarewarewa, in Rotorua, the Pohutu Geyser plays to 18 metres, sometimes much more. It is accompanied by the Prince of Wales Feathers, named for the angled nature of its display.

Above: Geyser Flat at Whakarewarewa, Rotorua. In an area of one square kilometre there are more than 500 thermal features including seven geysers.

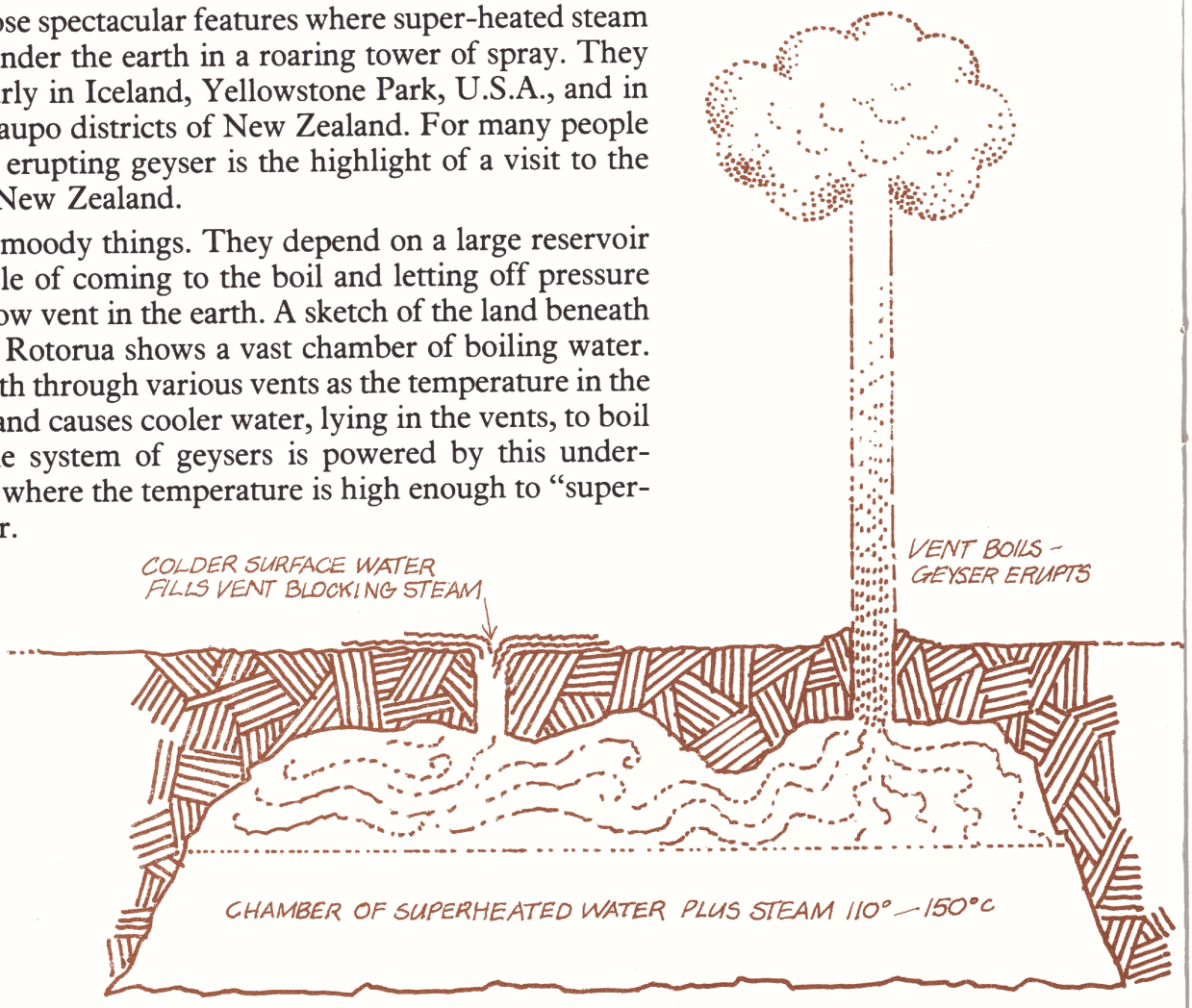


Right: Mahanga Geyser, the Boxing Glove, most active geyser at Whakarewarewa.

Geysers—superheated steam

Geysers are those spectacular features where super-heated steam escapes from under the earth in a roaring tower of spray. They occur particularly in Iceland, Yellowstone Park, U.S.A., and in the Rotorua-Taupo districts of New Zealand. For many people the sight of an erupting geyser is the highlight of a visit to the Hot Lakes of New Zealand.

Geysers are moody things. They depend on a large reservoir of water capable of coming to the boil and letting off pressure through a narrow vent in the earth. A sketch of the land beneath Geyser Flat at Rotorua shows a vast chamber of boiling water. This bursts forth through various vents as the temperature in the chamber rises and causes cooler water, lying in the vents, to boil too. The whole system of geysers is powered by this underground cavern where the temperature is high enough to "superheat" the water.


COLDER SURFACE WATER FILLS VENT BLOCKING STEAM
VENT BOILS – GEYSER ERUPTS
CHAMBER OF SUPERHEATED WATER PLUS STEAM 110°—150°C

The energy of the geyser begins deep within the earth. Here water may heat well above normal boiling point, while still remaining a liquid, for the pressure is higher than above ground. Temperatures of water can reach up to 374°C. under such pressure. This "superheated" water can explode or "flash" to steam and boiling water, if the pressure is suddenly released, and that is what happens when the geyser blows. Suddenly the cooler water blocking the narrow vent boils and allows the pressure below to escape. The superheated water flashes and the geyser erupts.

Some geysers are as predictable as clocks. Others vary their activity depending on the level of groundwater and even the direction of the wind. Pohutu at Rotorua is affected by wind for this may cool the ground, or sweep the falling water away from the geyser vent, so it does not fall back and quench the eruption.

Pohutu plays frequently, around 14 times a day, but its timing may be quite erratic. As pressure builds up within its reservoir, the nearby Prince of Wales Feathers erupts, a warning to watch for Pohutu.

Geysers take the form of a column of steam and water because their vents are extremely narrow. The throat of a geyser is usually lined with silica, giving it a smooth vent, through which water and steam under pressure can move in a rush.

The chemistry of the water may affect the timing of the blow. The practise of "soaping" a geyser can start an eruption. Near Waiotapu an artificial geyser, called the Lady Knox, is forced to erupt everyday by the use of soap. The geyser was made in 1906 by piping a hot spring thus creating a narrow vent up which steam and boiling water can rush. The soap appears to start a reaction so the water boils and steam bubbles form.

Where the throat of a geyser has been widened, perhaps by local collapse, the vent may no longer be narrow enough for the phenomenon of eruption to occur. Other extinct geysers about Rotorua and Wairakei have been blamed on shifting ground water levels and geothermal development. At Wairakei a number of spectacular geysers died when their source of superheated steam was tapped to produce artificial bores for power generation.

Perhaps the most spectacular of the New Zealand geysers was Waimangu which was active from 1900 to 1904. It reputedly played up to 500 metres at its peak. The geyser was born after the Tarawera eruption created a temporary lake. The new level of groundwater nearby created a reservoir for the superheated steam which erupted with such force that it carried mud and rock with it, layering the surrounding area with volcanic silt. In 1903, three tourists and a guide were killed by such an eruption. The geyser died when earth movements drained the nearby lake.

Waimangu Geyser in eruption, 1901. The bare landscape is a reminder of the desolation wrought by the recent eruption of Mt Tarawera.

Hot Springs

Water heated underground is the source of hot springs and pools. These springs may be boiling as they surface. Hot springs are frequently alkaline forming clear, often blue or green, chloride pools.

Boiling blue chloride pool at Orakeikorako, on banks of Waikato river.

Chloride pool at Whakarewarewa occupies the silica-lined vent of a former geyser.

Hot springs and fumaroles emit steam and gas beside silica flats: an active area of Ōrakeikorako.

Boiling waters of aptly-named Hell's Gate, at Tikitere near Rotorua. Pools here approach 100°C. Hell's Gate, itself, is a boiling whirlpool.

Hot Springs

Colour pictures on previous pages

Hot springs are the most widely scattered thermal wonder in New Zealand. They are even found in the South Island alps far from any volcanic activity. The reason is that hot springs begin with surface water which has trickled far underground to where the earth is naturally warmer. In the volcanic regions this can be quite shallow, where the molten rocks of the volcanoes reach close to the surface. In other places the warmth that heats the spring is part of the natural heat deeper inside the earth. With the temperature of the earth increasing some 30°C. with each kilometre of depth, water does not have to trickle far down before it comes in contact with hot rocks. Then heated the water rises, like a natural spring, carrying the warmth of the earth with it.

Hot springs do not usually boil though temperatures may be close to. The bubbling surface is often the sign of escaping gas.

The hot water carries with it chemicals from underground which can cause spectacular colours in volcanic regions. Such water is what chemists call alkaline or "soft" water. It carries much sodium chloride and is the cause of the deposits of silica which surround so many geysers and springs.

Hot springs are a free-flowing phenomenon. Some are not much more than air temperature: their presence is much more obvious on a frosty morning when they steam in the clear air. Others can approach 100°C. Dangerously temperatures may vary, within a metre or so, from safe to lethal.

At Whakarewarewa a hot pool called Parekohoru is used by Maori people for cooking—the temperature of the pool is 96°C.

Sometimes heated water rises into pools large enough to be regarded as lakes. Beside the Rainbow Mountain steam rises from lakes where hot springs bubble by the verge. Frying Pan Lake at Waimangu fills part of an eruption crater from the Tarawera eruption of 1886. The lake has an area of 4.9 hectares and a water temperature of up to 67 degrees. The area has erupted several times since the Tarawera eruption. The Inferno Crater nearby has a lake which rises and falls with its temperature, peaking and spilling over when the temperature reaches 84°C.

Beside the Waikato river, in the region between Taupo and Orakeikorako many springs send steaming streams into the river. Often hot waterfalls and warm pools are the product of streams running from hot springs nearby.

Postage stamp from 1935 Pictorial issue shows Maori cooking food in hot pool.

Mudpools and mud volcanoes

Boiling mud is perhaps the most disturbing phenomenon of the thermal regions. Its dark surface boils and heaves as volcanic gases seek to escape through its plastic surface. Some pools boil and bubble almost as freely as the chloride hot springs while others plop, threateningly, like sulking porridge.

The boiling, plopping rhythm of the mudpool comes from its temperature and the nature of the mud it contains. In dry seasons they can become more sticky for they have less water then.

Mud pools may exist beside hotpools, but their nature is different. Where a hot spring discharges heat above ground, the mud pool is the result of heat trapped below. The underground steam and gas mixes with the barrier of surface water and soil to make a hot mud.

The heat, held below, may cause chemical changes in the earth. The poisonous gas hydrogen sulphide which is produced by volcanic activity may oxidise in part to sulphuric acid, making acid springs and muds. From such mud comes a convenient source of several chemicals, some used in cosmetics and other health products. Some pools have a black mud often caused by very fine iron sulphide. Other pools have a pink or pale grey tone.

In summer the mud pool becomes heavier. Instead of boiling across its surface the escaping gases may concentrate on a particular corner of the pool. Mud, thicker and heavier without winter rains, begins to pile up about the vents of escaping steam. Something remarkably like a volcanic cone begins to build up. Now the mud leaps up in lumps from a tiny crater and plops down on the outside of the cone. The growing mudpile, with its central vent, may grow into a mud volcano.

Colour pictures on following pages

Fumaroles

Like small volcanoes these holes in the earth resemble gateways to the underworld. Often they hiss and roar with the sound of thermal energy underground.

The fumarole is a vent, where steam and thermal gases are discharged, like a chimney. Unlike the hotspring and the geyser they do not spray water upwards. Their fuel of boiling water and steam stays trapped below and the fumarole serves only to let some of the steam and gases escape.

Like mudpools, fumaroles may occur alongside hotpools and geysers in a thermal area. They are yet another natural form for reducing the pressure of volcanic gas and heat below the surface.

Mudpools

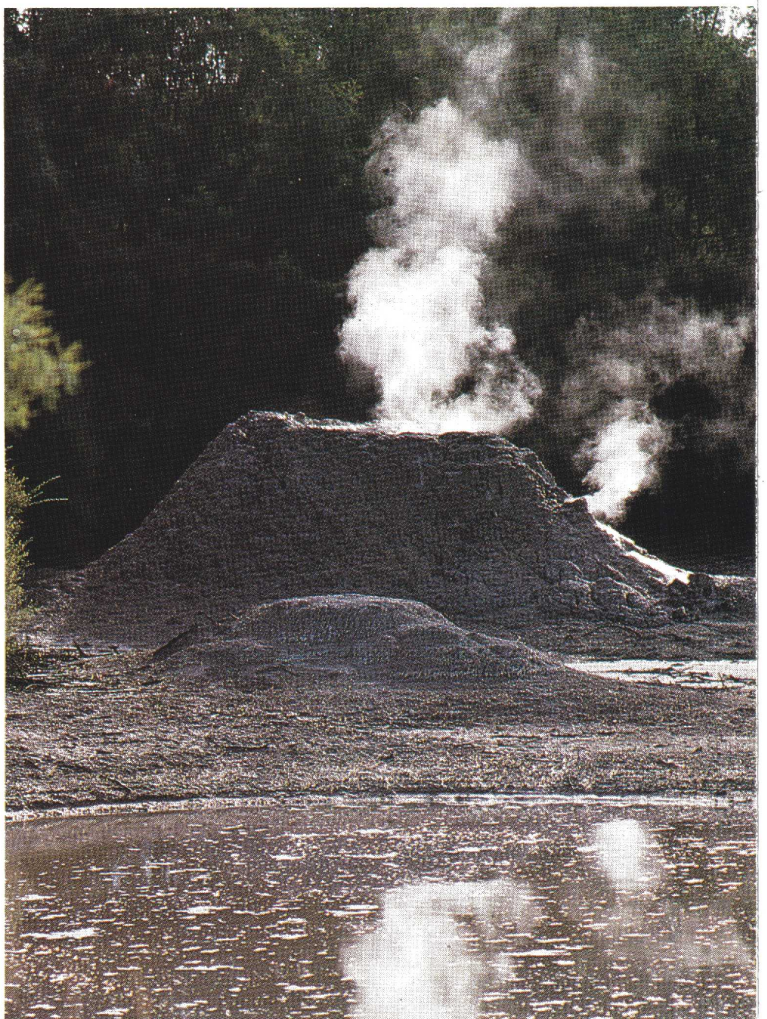
Where steam and hot water cannot reach the surface directly, mudpools may form instead. Underground heat liquifies the soil in a mixture with surface water. Mud volcano, at right, may form when surface water is scarce. Where water is plentiful mudpools have more liquid form.

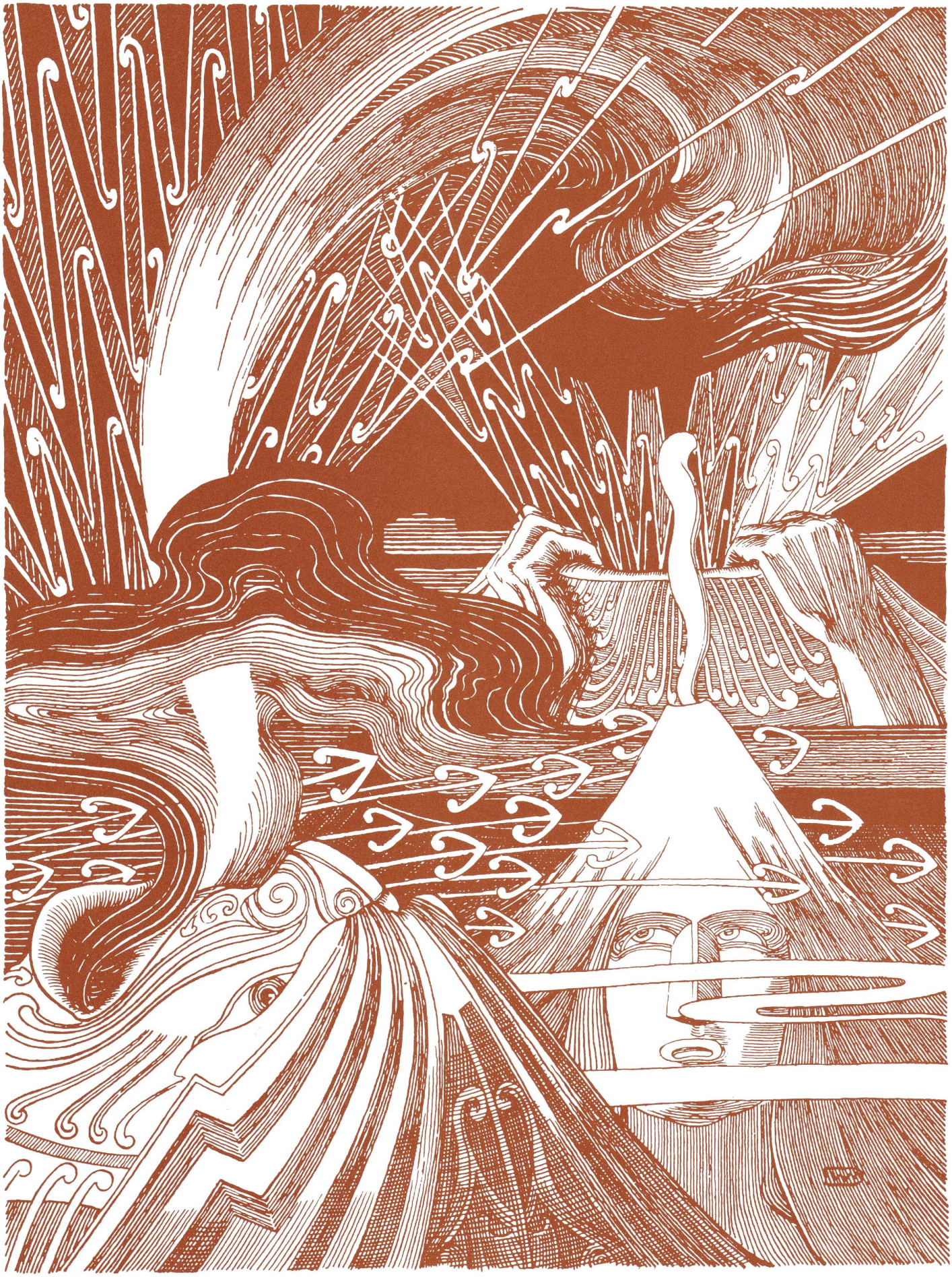
Above: Ngamokaiakoko, the Frog Pool, at Whakarewarewa, Rotorua.

Right: Mud volcano forming on golf course at Whakarewarewa.

Top left: Underground pressure mixes surface earth into boiling mud at Wairakei, near Taupo.

Bottom Left: Liquid mudpool at Whakarewarewa.





Maori Legends of the Volcanoes

The spectacle of the volcanoes inspired a wealth of stories to account for their origin and place. Maori settlement was comparatively dense in the region of the Hot Lakes. The chain of active volcanoes, hot-water lakes and mudpools, is carefully accounted for in the traditions of each tribe.

The Tongariro volcanoes rise to the highest point in the North Island (Mt Ruapehu is 2797 metres) and their summits were sacred to the Maori. Ngatoro-i-rangi who climbed the mountain to claim it was caught in one of those frequent snow storms that engulf the peaks in any season. Crying to the gods for help he saw the fires of his homeland, the volcanoes of Hawaiiki, advance inland by way of Whakaari (White Island in the Bay of Plenty), through the Rotorua and Tarawera districts, along the shores of Taupo to the mountain tops of Tongariro. Thus, in saving his freezing body from the onslaught of the snowstorm, Ngatoro brought the warmth of the thermal regions to Aotearoa.

The Battle of the Giants

The volcanoes of Aotearoa battling for the love of a female mountain. This drawing made by W. Dittmer about 1900 makes the mountains into the warriors of legend. His version has Ruapehu and Taranaki fighting for Tongariro. Maori versions have Tongariro as the successful lover of Pihanga, with the others departing; Taranaki down the course of the Wanganui river, while Tauhara and Patauaki moved northward to Taupo and Kawerau.

The great volcanoes of the North Island themselves are said in legend to have come from Tongariro. The Battle of the Giants, depicted opposite by W. Dittmer in *Te Tohunga,* is an account of how the male mountains fought for the love of Pihanga, a gentle dome still clothed in forest, which lies on the southern shore of Taupo. Their night of battle led to the defeat of the other mountains by Tongariro.

Taranaki set off to the west, gouging the channel of the Wanganui River as he left. The others, defeated, marched north towards the Bay of Plenty. Mountains may only move by night but by morning Patauaki had reached the plains of the eastern Bay of Plenty where he stands, above Kawerau, with the European name of Mount Edgecumbe. Tauhara moved more slowly, often looking back and reached only the northern shore of Taupo by dawn. Tauhara broods now, looking down the lake, at his lost love Pihanga and her conqueror Tongariro beyond.

Not surprisingly there are many local stories which recount the relation of ancestors to particular features. The hotpool of Mokoia Island in Lake Rotorua, for example, features in several stories. When Hatupatu escaped from the clutches of the bird-woman, Kurangaituku of the Tokoroa district, he returned to his parents' home by swimming the cold lake. He was discovered by their servant recovering from the cold, sheltering in the warm waters of the pool beside the lake. Here too, Hinemoa recovered from her night-time swim, across the lake, to reach her lover Tutanekai.

The features of volcanic mountain, geyser, mudpool and hot lake, excited a host of stories and traditions explaining their form. Often the Maori names of such features survive today and may invite the curious to establish their origin.

Summit, Mt Tarawera

Frying Pan Lake, Waimangu

Tarawera Eruption

The 1886 eruption of Mt Tarawera created a series of craters extending from the mountain top above, through Lake Rotomahana to Waimangu at bottom left. The fissure runs for 13 kilometres. Frying Pan Lake, Waimangu, occupies the Echo Crater of the 1886 eruption. Fed by hot springs the lake varies in temperature, discharging at 55°C. The red scoria of Tarawera craters was produced by the 1886 eruption but overlays the white pumice and grey rhyolite of a previous eruption 700—900 years ago.

Crater rift atop Mt Tarawera

The Tarawera Eruption 1886

Contemporary picture of Mt Tarawera in eruption was made by Archibald Willis. (Courtesy, Auckland Institute and Museum Library).

Historic photographs, courtesy Auckland Institute and Museum Library.

Tarawera 1886—The Night Of Horror

New Zealanders give little thought to the possibility of a major volcanic eruption yet it is only 100 years since the spectacular explosion of Tarawera near Rotorua on 10 June 1886. In less than 24 hours this volcanic dome was rent asunder creating a line of craters along a 13-kilometre rift. Ash buried the surrounding countryside up to 45 metres deep and 153 people died.

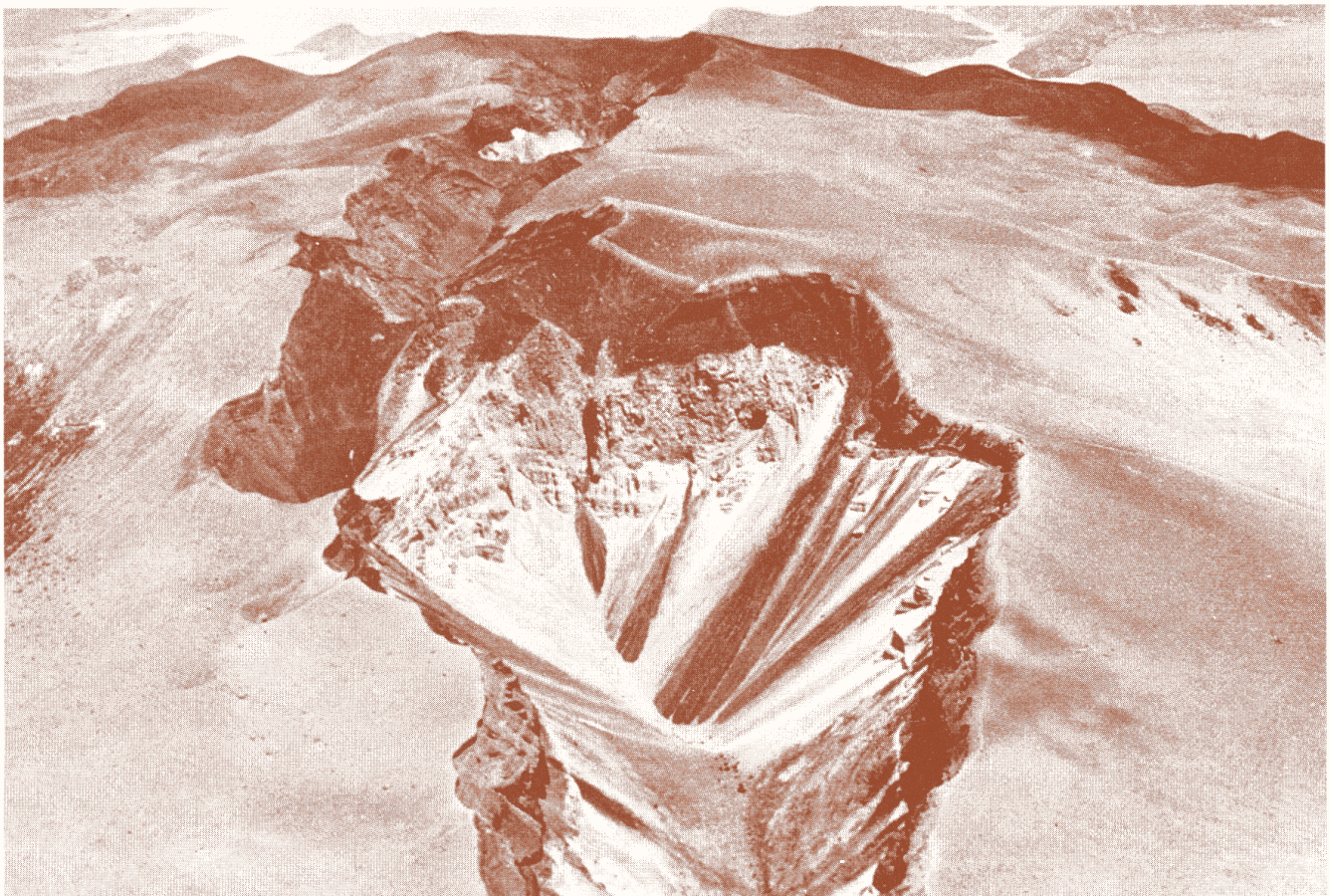
The volcanoes of the Okataina volcanic zone have been a major force in shaping the Hot Lakes. A look at the succession of ash showers which have buried the country around Rotorua city reveals major eruptions 700—900 years ago and again at 5000, 7000, 9000, 11,000, 13,000, 15,000, and 19,000 years ago. The 1886 eruption was the smallest.

Top left: Desolated landscape in Rotomahana area after the Tarawera eruption.

Bottom left: Ruins in the village of Wairoa following the eruption. Now excavated in part, Wairoa is known as the Buried Village, a tourist sight near Lake Tarawera.

Below: Craters of Tarawera photographed following the eruption of 1886.

The Tarawera eruption destroyed the famous sinter terraces at Rotomahana which had been attracting artists and tourists from all over the world. Now tourists on boats, passing down the lake which flooded the Rotomahana crater, can see only drifting steam where once the Pink and White Terraces stood. Further away at Waimangu the eruption opened Echo Crater which has since flooded to form the Frying Pan Lake, and Inferno Crater also filled by scalding water. Southern Crater, now filled with cold water, marks the further extent of the eruptions which began high on the dome of Tarawera and extended down its flank to Waimangu almost in a straight line. Waimangu is still unstable: several people died in spectacular local eruptions about Frying Pan Lake (or Echo Crater) earlier this century.



Above: Silica Springs, Mt Ruapehu

Volcanic Beauty

The rich colours of the volcanic regions may be the product of chemistry or simple plant life. At Silica Springs, near Whakapapa Village on Ruapehu, the white sinter deposited by the springs is richly-coloured with brown algae. Colonies of these single-celled plants flourish in the warm water. At right one of the collapsed craters at Waiotapu shows the results of mineral deposits. The broiling grey water is produced by sulphur as are the yellow deposits about the vent. The bright red colour in foreground is iron oxide. Photographs at left depict colonies of algae growing in hot springs and streams: the colours vary with the temperature.

Right: Mineral colours, Waiotapu

Left: Algal colours, Waimangu

Volcanic Colours—an artist's palette

Volcanic action produces a rich variety of earth colours. In various regions of New Zealand, formed by ancient volcanic activity, the colours of soils and rocks still indicate their origin. The pink and white road cuttings of the Volcanic Plateau, formed of ignimbrite sheet, are one example; the red soils of some Northland road cuttings are another. Looking closer however there can be pockets of purple and yellow too. Chips of volcanic glass may be interlaid with layers of white pumice. The origin of volcanic rocks, melted out from deep underground and exploded under the force of gas, can change shapes and forms of rock.

On a smaller but spectacular scale the action of thermal springs may bring to the surface the traces and stains of rocks buried below. The deposition of these rocks, as the hot water cools, can create a colourful landscape. Mudpools too can present a further range of colours. The vents of fumaroles deposit chemicals from underground. The very heat of the thermal water as it runs from the springs can create a warm environment for colourful algae. It is therefore not surprising that there are several volcanic places which claim for themselves the name of "artist's palette" or something similar.

Some of the deposits are easy to identify. Yellow crystals of sulphur often form about the mouths of fumaroles, made from the sulphide exhausts of volcanic gas. The chalky sinter which makes up the ground around many volcanic hot springs is white silica, though this in turn may contain other minerals brought to the surface by the hot water, including gold and silver. Purple rock may contain cinnabar. Iron produces yellow, brown and red. Grey is also the product of sulphur.

Water may vary in colour too. Blue chloride pools created by naturally alkaline hot pools are common. Concentrations of other elements may produce variety: orange is produced by antimony and green by ferrous iron.

The source of much of the colour in areas of volcanic hot water is the simple plant alga. Colonies of this single-celled life form thrive in the hot water. Algae are often described as "slime" when they flourish in stagnant water but about the silica terraces they provide stains of rich colour. The brightest colours are said to be caused by algae which suffer the hottest water—perhaps up to 60°C. Thus there may be yellows, darkening to oranges and reds. In cooler areas brown and green algae flourish. Often the colours change within a few centimetres, depending on the flow of thermal water, giving the ground about a beautiful streaked appearance.

The Thermal Habitat

Gulls nest on silica flats by Lake Rotorua within protection of thermal activity.

While some volcanic places have been adapted for mass tourism many of the thermal areas of New Zealand retain a wilderness flavour. As protected scenic reserves they display a range of plants and natural wonders especially adapted to the volcanic environment. For in these places the ground is often very hot and its chemical composition unsuited to normal plants.

The typical thermal area consists of mudpools and hotsprings, scattered across a landscape of strangely-coloured earths, and surrounded by scrub. Walking along a rough track, through a brushwood of manuka, there are distinct sounds of bubbling mud and hissing steam. To step off the track is usually dangerous, for the plants grow often on a very thin skin of earth over reservoirs of underground steam and poisonous gas. Yet the plants survive.

Manuka scrub and pin-leaved mingimingi are the most obvious shrubs for they have a great tolerance of harsh conditions. Native grasses grow with the hebe Koromiko. Their roots are sometimes in ground with temperatures well above those in the upland air which surrounds them. A survey by the Department of Scientific and Industrial Research revealed ground temperatures of from 60°C. to 90°C. about some of the houses in Rotorua. The shrubs of the volcanic areas will also grow within inches of the boiling pools.

The over-heated ground is composed of the strange chemical mixes of earth produced underground. Often they are soils devoid of nitrogen. The sundew Drosera adapts to this by getting its nitrogen from the insects it captures in its carnivorous leaves. Nevertheless wild orchids grow in this inhospitable environment. They grow to perhaps 20 centimetres high, their delicate flowers appearing from October, flourishing in the "hothouse" atmosphere of drifting steam.

Aerial top-dressing of cobalt brought new life to pumice soils. Postage stamp of 1960s.

The warm surfaces of the hot lakes allow an extended season for aquatic insects, such as midges, which may continue breeding into the depths of winter. This presence of masses of insects attracts lizards and birds. It is not unusual to see the pied fantail (a flycatcher), and the welcome swallow swooping in the steam drifts above lake and spring, hunting insects.

An interesting aspect of the nature of these volcanic soils is the disease called "bush sickness". For many years the volcanic lands about Taupo, and north across the volcanic plateau, remained largely unsettled. While the soil grew good grass, cattle and sheep sickened and died. In the 1950's the problem was traced to the absence of an essential element, cobalt, from the soil. Now topdressed with a trace of cobalt the land produces healthy pastures and sound animals.

Champagne Pool at Waiotapu

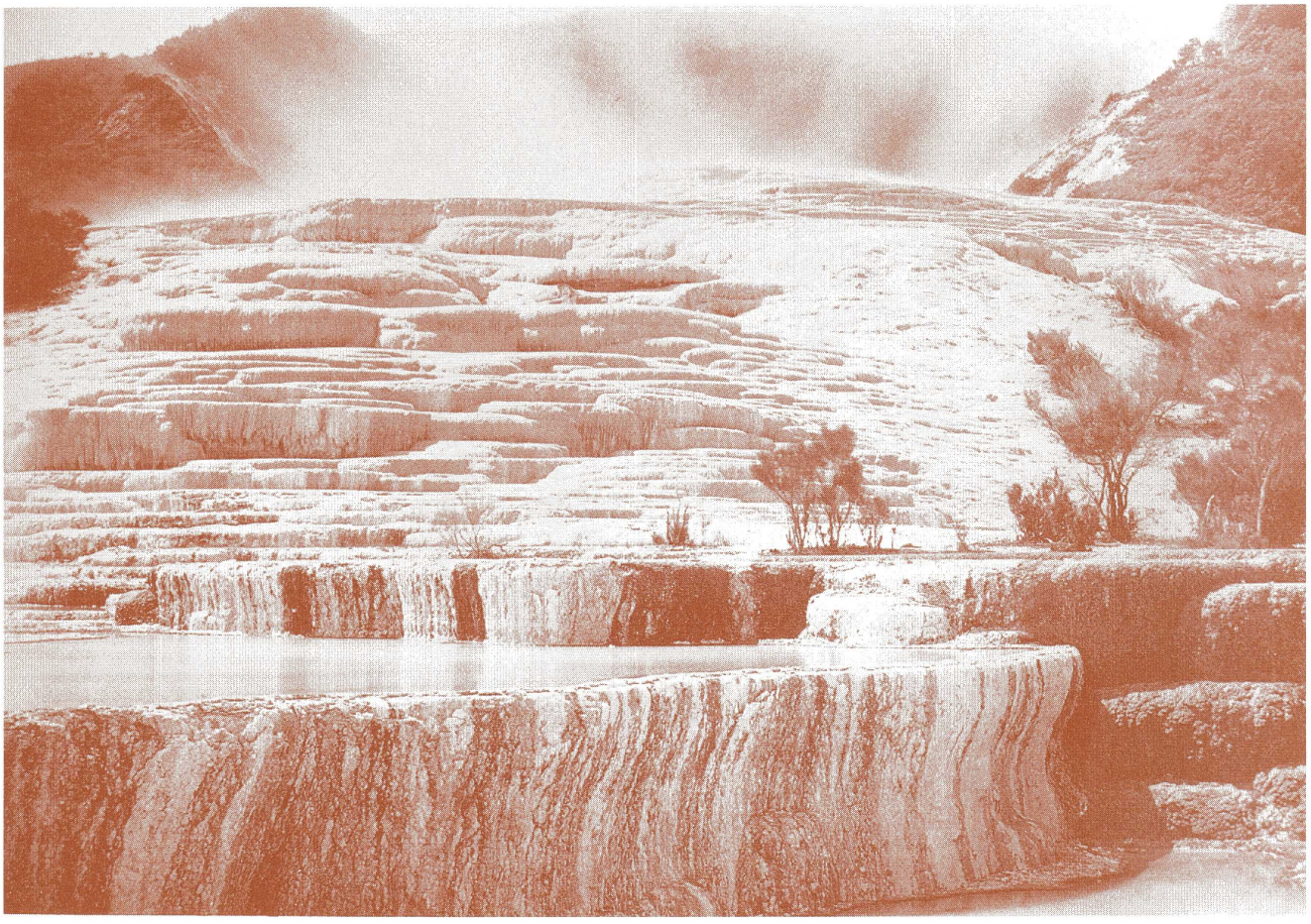
Valley floor at Waiotapu is coated in silica produced over centuries by hot springs upstream.

Close view of sinter at Waiotapu shows delicate form of silica deposits.

Silica and Sinter

Silica is the substance from which sinter terraces and other delicate landforms are made. At left an extensive deposit of silica covers the floor of a valley at Waiotapu—some 50cm has been deposited in perhaps 900 years. A closer look reveals its delicate surface, miniature terraces of primrose sinter, formed from silica deposited from the running hot water from the Champagne Pool and other hot springs.

Pictured above is the silica-coated edge of a fault and terrace at Orakeikorako, on the Waikato River, near Taupo. Much of the colour is produced by algae living in the hot water. The little Diamond Geyser at right produces delicate forms of sinter, as silica brought up from underground, deposits about the vent.



Sinter—the source of terraces

When the Victorians discovered the Pink and White Terraces of Rotomahana they were likened to a ninth "wonder of the world." The steps of coloured stone, each containing delicate pools of trickling hot water, were made of sinter. While the terraces were to vanish overnight, in the eruption of Mt Tarawera in 1886, there are other places about the Hot Lakes where sinter terraces still make outstanding features. Some of their colours are due to subterranean chemicals deposited on the surface by thermal springs. Others are produced by the mass of primitive plants called algae which form colonies in the hot running water.

Sinter is formed from silica brought to the surface by hot water. Its source is in the subterranean volcanic rocks. On the surface the silica may deposit as rims about the mouth of a geyser or hotpool, or it may spread out into banks and flats or terraces.

The deposit of silica is a slow but measurable process. In earlier times people put objects into hot streams bearing silica so that these became, in time, coated with sinter. Bottles and shoes "turned to stone" are sometimes seen in collections of novelties at tourist centres. On a much larger scale an early guide, Alfred Warbrick, created what are now the Warbrick Terraces at Waimangu. Here, bereft of the Pink and White Terraces which had once been the major attraction, Warbrick put bags of sand into a hot stream. Coated in silica and coloured by colonies of algae they have created an interesting tourist attraction which looks as if it is born of natural causes.

The Pink Terraces at Rotomahana destroyed in the Tarawera eruption of 1886

The White Terraces

Natural terraces of sinter may be seen at Whakarewarewa where they coat Geyser Flat, at Orakeikorako on the Waikato River, and spectacularly at Waiotapu. Sulphur Flat which forms much of the lakeshore by Rotorua is a similar product of sinter deposited by the still-active hot pools.

Colour pictures on previous pages

The sinter terraces at Waiotapu fill a whole valley as it curves away from the active hot springs like the Champagne Pool and the Artist's Palette. Sinter here has put a skin over the land perhaps 50cm in the past 900 years.

Where hot water flows over banks it may form sinter falls and terrace edges. The nature of the fall may shape the sinter into delicate forms. At Waiotapu delicate frills, like gathered muslin, form the Bridal Veil Falls where the thermal water drops into a river below.

At Orakeikorako spectacular sinter terraces fall to the Waikato River. Silica from the hot water falls has coated the scarps of faultlines above the river. To one side a geyser has built a delicate cone of sinter, like coral, through the action of splashing water. The terraces at Orakeikorako are claimed to be more than 20 metres thick in places.

Living with Volcanoes

Despite the ever present risk of renewed volcanic acivity New Zealanders have become accustomed to living with volcanoes. Indeed, in places they have even harnessed the energy of the earth to help them. While some geologists monitor the pressures about the active volcanic areas, as a possible warning of renewed activity, others have advised on the development of geothermal power schemes and even the domestic use of geothermal steam.

The risks of renewed eruption continue in several zones of New Zealand's volcanic regions. The weakness in the earth, where the continental and oceanic plates work against each other, remains an active belt causing earthquakes and melting the rock below into reservoirs of magma and gas. The historic eruption of Tarawera is a reminder of the forces that may break forth in this region at any time. The nature of some apparently extinct volcanoes, such as Taranaki, is deceptive too. Taranaki is, in fact, only dormant and, based on its earlier cycles, could well erupt again—violently at any time. It last erupted in the eighteenth century. The main activity about the Auckland isthmus was some 50,000 years ago, yet Rangitoto is thought to have erupted only 700 years ago and there are some suggestions that it was still active less than 300 years ago.

The nature of the Auckland volcanoes is gentle for they are of the basalt type, which quite quickly raises a scoria cone, then dies. The volcanoes of the Rotorua, Taupo and Taranaki kind have a reputation for more violent activity. It is only because New Zealand has such a short history of settlement that the catastrophic effect of these eruptions is largely known only to geologists.

The Department of Scientific and Industrial Research now continually monitors the activity of the Tongariro volcanoes. Mudflows have rushed down from the crater lake into the skifields of Ruapehu in recent years making an evacuation procedure essential, for this area may have 10,000 visitors at a weekend. Ruapehu and Ngaurahoe erupt spectacularly every few years and there is further activity on the slopes of adjacent Mt Tongariro.

Nevertheless New Zealanders have built towns adjacent to active volcanoes. They are popular tourist resorts with people coming from all over the world to sample life on the restless earth. The hotsprings which break through the earth have long been popular as health spa. In Rotorua, an extensive geothermal field underlying the town has been tapped for hot water and central heating. Nowadays systems use the underground steam only to heat separate water supplies, by exchange of heat. Direct use of geothermal steam is dangerous. The pressure of underground bores, used directly, can cause a "wild bore" in the

OHINEMUTU MAORI VILLAGE
A popular spot with sightseers in Rotorua, Ohinemutu is just one of several Maori settlements which were located on active thermal fields. The warmth was welcome relief in the frosty winters. Hot pools were used for cooking.
House sites at Ohinemutu are carefully chosen. Many have vents and hot springs in place of gardens. Soil temperatures here may exceed 70°C. Houses require careful underfloor ventilation to prevent the build up of deadly volcanic gas—largely hydrogen sulphide which gives the area its distinctive "rotten eggs" smell.
St Faith's Anglican Church stands on a narrow neck of land extending into the cold lake. The land around it often erupts in hotpools and fumaroles.
Steaming water is from hot pools and springs nearby.

backyard. There are many stories of how such steam vents have caused damage in the city.

Besides the possibility of fresh eruptions of underground water there is the risk of death by poison gas. Geothermal steam bores bring to the surface gases from underground, giving the "rotten eggs" smell which is so characteristic of these regions. This gas is hydrogen sulphide. It lies more heavily than air and thus accumulates in excavations. Until more care was taken with the design of buildings and baths in Rotorua, hydrogen sulphide frequently claimed the lives of unfortunate people who were caught in a pocket of the gas. There are signs in the Rotorua public gardens which warn of the presence of poison gas. Another part of geothermal gas is made up of carbon dioxide which has also been known to build up sufficiently to cause death by suffocation.

The tapping of underground steam has ruined some of the more spectacular thermal activity. In Rotorua there are more than 900 wells drilled into the hot water zone below the city. At least half are now defunct. While much of the water is returned underground, after use in the heating process, conservationists blame this for diminished activity in the thermal fields nearby.

Bathing on the White Terraces at Rotomahana.

At Wairakei, where geothermal steam has been tapped to generate electricity, a once-spectacular valley of geysers and other forms of thermal activity, has lost much of its surface display. Again, there is argument between those who would use the energy and those who see it as a natural wonder to be protected for tourism.

Besides the danger of eruption and poison gas, geothermal water is also known to harbour an amoeba which causes cerebral meningitis. For this reason most modern pools now use the geothermal water only to heat fresh water through a heat exchanger. Natural hot pools in contact with the earth may be contaminated. Where hotpools draw their water direct from the ground bathers are warned not to put their heads under or dive into the water.

Probably the biggest danger in hot spring areas, however, is the risk of getting scalded. The warning signs have very real meaning where the earth is thin and temperatures approach boiling point.

Making use of thermal activity

The appeal of volcanoes and geysers has drawn tourists to the Hot Lakes district of New Zealand for well over 100 years. The village of Wairoa, buried in the eruption of Mt Tarawera, existed as a staging post on an early tourist route through Tarawera and Rotomahana. The fascination of thermal wonders for sightseers however, is not the only commercial value.

Volcanic activity produces minerals of considerable value. Yellow deposits of sulphur are common though attempts to mine it have often failed, when the thin crust of the earth erupts in fresh activity as the chemical is removed. On White Island, an active volcano in the Bay of Plenty, a party of miners was buried by a hot mudflow when the crater wall collapsed killing 11 in 1914. The workings were abandoned though another attempt was made to extract sulphur in the 1930's. Now many volcanic mineral deposits are additionally protected, in tourist resorts, by law for many are classified as scenic reserves.

The rocks produced by some volcanoes however, are widely used as building materials. About Auckland many of the little basalt cones have been mined away, over the past 100 years, as a source of scoria road metal. Building stones such as basalt are, originally, the product of volcanic out-pourings.

Steam from geothermal bores has been piped to heat homes, factories and swimming pools. The hot water is also used for heating glasshouses and the steam in industrial processes such as drying timber, or bending it.

The various chemical compositions of thermal water and mudpools have led to the use of such springs in health spa. The use of thermal water for the treatment of rheumatism and muscular disorders led to the construction of the Government Baths in Rotorua. Pools of different chemical composition and temperature were favoured for various ailments. Mudpools, rich in chemicals like sulphur, are used in the treatment of skin diseases. Thermal spa have been developed in a number of places beyond the Rotorua district. In places as distant from each other as Ngawha Springs in the Far North, and Hanmer Springs in Canterbury, people still come to "take the waters."

The most significant use of geothermal energy in New Zealand is perhaps the geothermal power station, built during the 1950's at Wairakei near Taupo, and the development at Ohaaki (Broadlands) between there and Rotorua. These fields take steam pressure from underground and pipe it into turbines generating electricity. New Zealand achievements in this field have led to the development of further fields overseas, in South America, Indonesia and Phillipines. The Wairakei field produces 192 megawatts, about the size of a conventional hydroelectric power station on the nearby Waikato river.

Wairakei Geothermal Field. Pipelines taking superheated steam from around 100 bores to a power station generating electricity beside the Waikato River, near Taupo.

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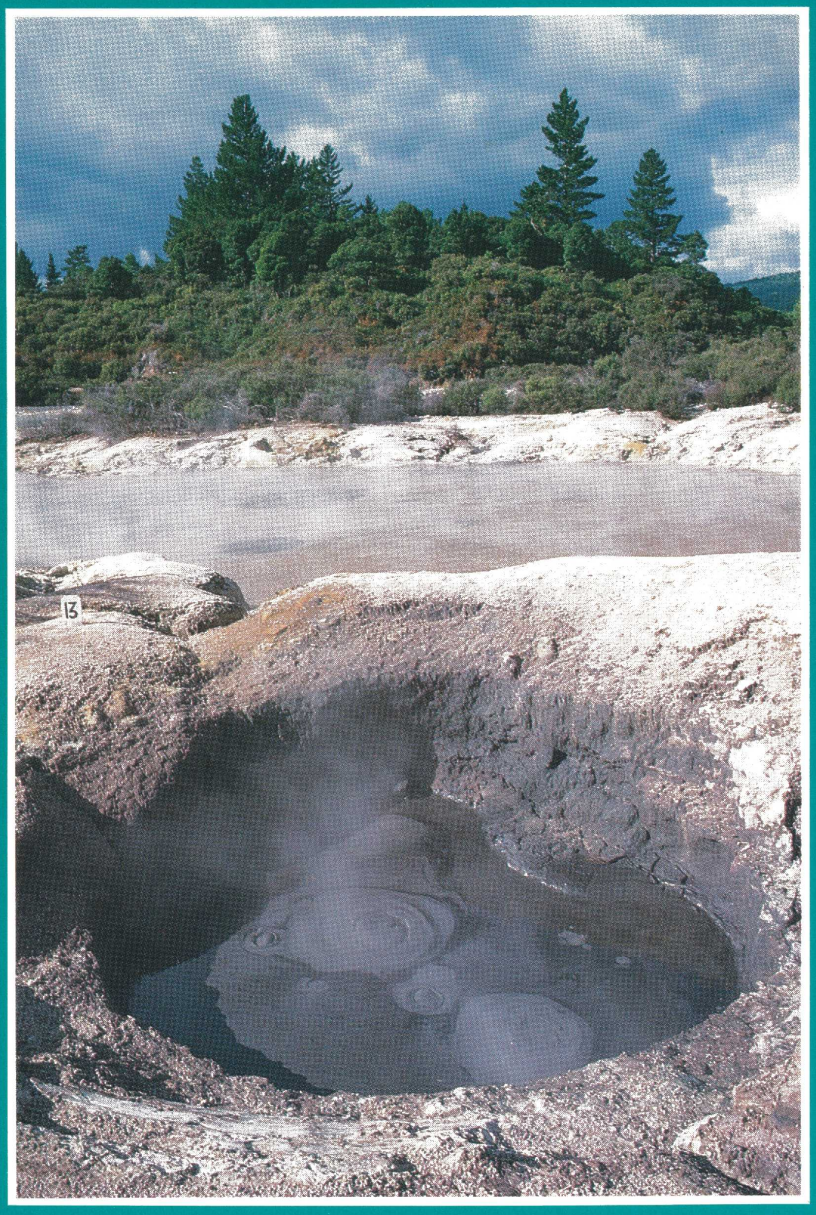
G.C.E., Takapuna, 1985.



Hot Lakes
Volcanoes
Fumaroles
Mudpools
Geysers
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Terraces
Eruptions
in colour

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